Protocol

Title

The effectiveness of concept mapping as a tool for developing critical thinking in undergraduate medical education – a BEME systematic review.

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Abstract

Background - There are inconsistent claims made about the effectiveness of the concept maps (CMs) in medical education. The use of CMs aims to respond to the need for meaningful learning, that clarifies knowledge and improves critical thinking, but research gaps persist.

Aims - The three main research questions are: 1) What studies have been published on concept mapping (educational *intervention*) in medical students (*population*)?; 2) Whether these studies have impacted the student's critical thinking (*outcomes*)?; 3) How and why have these interventions had educational impact?

Methods - Peer-reviewed literature and gray literature about the use of *novakian* concept maps in undergraduate medical teaching will be included. We will search electronic databases (PubMed, Scopus, Web of Science, Embase, Academic Search Complete, ERIC, CINAHL and b-on), expert reports, and hand-search key journals and the reference lists of literature reviews. Eligibility assessment and data extraction will be performed independently by 2 reviewers. Extracted data will include study characteristics, study design, concept map definition, how were concept maps used, educational outcomes, and resource use. The two major areas which will be considered are quality of the study design and quality of reporting to support replicability.

Keywords - concept map, concept mapping, medical education, critical thinking, undergraduate, meaningful learning, learning outcomes, evaluation.

The topic was successfully registered with BEME on 8th June 2021, with Reg No 0155.

Sources of support: Not applicable.

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Background

Critical thinking can be defined as the ability to think clearly and rationally about what to do or what to believe and is essential for the practice of medicine (Sharples *et al.*, 2017). Medical students need not only a broad knowledge base from basic sciences, but also the development of intellectual skills such as *critical thinking* and reasoning power, which can be expected to facilitate the resolution of future medical problems and decision processes (Swanwick *et al.*, 2019). In fact, the ability to think critically is a key competence, and an essential life skill relevant to decision making in many circumstances (Sharples *et al.*, 2017). On the other hand, the experience acquired from clinical practice, through chains of practice*,* apparently is not enough for medical students to become experts in medical diagnosis and decision-making (Groves *et al.,* 2003). The chains of practice are present in the reasoning of many experienced clinicians. They are based on practical knowledge which integrates clinical and basic science knowledge (Vink *et al.*, 2015). Students need to use metacognition, that is the need to think about their own thinking and learning. To integrate biomedical and clinical knowledge, the traditional forms of text-based learning do not seem to provide a way to achieve this ability (Groves et al., 2003). Methods of teaching and learning that provide transparency to the clinical reasoning process through networks of understanding are needed (Kinchin *et al.*, 2008). These networks of understanding are ways of organizing knowledge structures that explain how the elements are connected and why the practice chain must be adapted to changes in context.

According to Pinto and Zeitz (Pinto & Zeitz, 1997), concept maps (CMs) can facilitate students' understanding of the organization and integration of important concepts. By connecting old and new knowledge, this type of learning clarifies knowledge, improves *critical thinking* and assists in completing missing knowledge (Daley *et al.*, 2016). CMs are graphic representations of knowledge, that connect concepts in a *meaningful* way, used in education since its first description in 1984 by Novak and Gowin (Novak, 2003). CMs are based on Ausubel's constructivist theory, which assumes that learning of new knowledge relies on what is already known (*meaningful learning*), promoting long-term retention of the information in a usable, integrated network (Pinto & Zeitz, 1997).

There is a heterogenous use of concept maps described in many studies, and some maps do not meet the concept maps criteria, therefore not being *novakian* concept maps (Cañas *et al.*, 2015). Martin Davies described the following criteria for the *novakian* maps: 1) develop a declarative-type focus question; 2) brainstorm concepts and ideas and dispose the concepts circles or boxes to designate them as concepts; 3) put concepts in hierarchical order; 4) link lines are then provided between the hierarchical concepts from top to bottom; 5) devise suitable cross-links for key concepts in the map to show the relationship between the key concepts; 6) add examples to the terminal points of a map representing the concepts (Davies, 2011).

With the increasingly common trend in medical education to create integrated medical curricula (Brauer & Ferguson, 2015), concept mapping can be considered as an important tool to facilitate efficient teacher-learner interactions from the classroom to the bedside promoting better learning outcomes (Pierce *et al.*, 2020). In addition, the use of concept mapping in medical education aims to respond to the need for *meaningful learning,* but research gaps persist. Concept maps seem to allow educators to develop a more granular construction of an integrated network of learning units, but further research is needed to explore the relevance and integration of concept mapping in the *undergraduate* medical curriculum (Daley *et al.*, 2016). In the BEME Guide No.61 (Pierce *et al.*, 2020), concept maps were one of the effective strategies for teaching clinical reasoning in the clinical setting, but most of the evidence comes from studies in nursing students. Since clinical reasoning is conceptualized differently across health professions, it is relevant to perform a focused review on medical students (Young *et al.*, 2020). The existing literature reviews on the

topic focus on the educational effectiveness of concept maps. However, health educators also need to know what resources are required to implement concept maps.
This review will build on the evidence from Cason Pierce *et al.*, BEME Guide n.61 (Pierce *et al.*, 2020), and Barbara J. Daley *et al.* (Daley *et al.,* 2016). The primary goal is to assess the effectiveness of concept maps to promote *critical thinking* in *undergraduate medical education*.
The findings of this review can provide guidance for future research and educational practice in medical education, which is necessary to explore the relevance and integration of concept mapping in the *undergraduate* medical curricula.

Review Questions, Type of review and keywords

Review Questions

The primary goal of this review is to expand our understanding about the effectiveness of the CMs in *undergraduate medical education* by reviewing the current body of research. We aim to answer three research questions:

1. What studies have been published on concept mapping (educational *intervention*) in medical students (*population*)? (**Description**)
2. Whether these studies have impacted the student's critical thinking (*outcomes*)? (**Justification**)
3. How and why have these interventions had educational impact? (**Clarification**)

Ultimately, knowledge gaps identified from studies related to resources required to implement the use of CMs (teacher training time and software, amongst others), will be considered for reflection.

Type of review

In this effectiveness systematic review, we aim to analyze the effectiveness of CMs as an educational intervention. BEME reviews often seek to answer questions that align with different synthesis methods and drawing from a diverse landscape of review traditions. In this BEME review, a segregated approach to mixed method synthesis will be used (Pearson *et al.*, 2015). While to the best of our knowledge no prior reviews have formally used mixed methods systematic reviews, many earlier reviews combined qualitative and quantitative evidence using principles of mixed methods synthesis (Grafton-Clarke *et al.*, 2022; Yang *et al.*, 2022). It will contribute to know how CMs are used, what are the resources required, what assessment methods are used to evaluate the impact of the use of CMs and what are the knowledge gaps in this field.

Keywords

Concept map, concept mapping, medical education, critical thinking, undergraduate, meaningful learning, learning outcomes, evaluation.

Methods

Definitions

Concept map - a schematic device for representing a set of concept meanings in a framework of propositions (Novak, 2003).

Critical Thinking - ability to think clearly and rationally about what to do or what to believe, that is essential for the practice of medicine (Sharples *et al.*, 2017).

Meaningful learning - acquisition of "useful" knowledge, that is stored in such a way that it can be accessed from different starting points, is well integrated with previous knowledge, and is accompanied by the building of multiple representations (mental models) connected to other models for many other phenomena (Michael, 2001).

Novakian concept map - according to Martin Davies, a *novakian concept map*: 1) develops a declarative-type focus question; 2) brainstorms concepts and ideas and dispose the concepts circles or boxes to designate them as concepts; 3) puts concepts in hierarchical order; 4) links lines are then provided between the hierarchical concepts from top to bottom; 5) devises suitable cross-links for key concepts in the map to show the relationship between the key concepts; 6) add examples to the terminal points of a map representing the concepts (Davies, 2011).

Undergraduate medical education - or basic medical education refers to the period beginning when a student enters medical school and ends with a primary qualification in medicine, enabling them to practice with increasing clinical autonomy. This period of education comprises a pre-clinical and a clinical period.

Study Selection

Inclusion criteria

- Study design: experimental (randomized trials, non-randomized trials, interrupted time-series, regression discontinuity designs, pre-test post-test designs, removed treatment designs, repeated treatment designs), observational quantitative (cohort, case-control, cross-sectional), qualitative studies (qualitative descriptive studies, grounded theory, ethnography, phenomenology, action research) and mixed methods studies.
- Participants: studies performed within *undergraduate medical education*, in any teaching area.
- Intervention: studies describing the use of *novakian concept maps*.
- Language: due to limited resources for translation, we will include studies written in English, Portuguese, French, German, or Spanish.

After elimination of duplicate entries, all titles and abstracts will be reviewed independently for eligibility by two authors. Full text copies will be obtained for all studies considered as potentially eligible by at least one of the reviewers. The same two authors will independently assess the full texts to make a final judgement about study eligibility. If disagreements exist at this stage, they will try and solve disagreements by consensus and, if necessary, involve a third reviewer. Kappa statistics for reviewer agreement in study selection will be computed. There will be no analysis of study quality or risk of bias during study selection. Study identification and study selection will be summarized in a Prisma flow-diagram.

Search Terms

Electronic databases will include PubMed, Scopus, Web of Science, Embase, Academic Search Complete, ERIC, CINAHL and b-on. Hand searching will include Academic Medicine, Medical Education, Advances in Health Sciences Education, Medical Teacher and MedEdPublish. Gray literature sources will include Google Scholar, websites of concept maps and reports from experts and researchers in the field. We will search additional papers in the reference lists of reviews detected in the initial search. The BAT will have the support of the Librarian of NOVA Medical School.

The research terms will include "concept map", "conceptual mapping", "medical education", "medicine", "undergraduate", "critical thinking", "meaningful learning" and "knowledge maps", “cognitive maps” and “visual maps” to not exclude studies in which concept maps have been used under a different name.

Data Extraction

After selecting the eligible articles, data will be extracted to Google sheets, to allow quick review and sharing the results inside the BAT. Extraction will be completed by two authors independently and differences resolved through discussion or involvement of a third author until a full consensus is reached.

A data charting form will be developed and piloted on the first 10 studies meeting eligibility. We plan to extract the following items:

- study identifiers (authors, title, journal, type of article, publication date)
- country / city and university
- study aim (the use of concept maps is the primary objective, or are others present)
- study purposes of education research: description, justification, and clarification (Cook *et al.* 2008)
- inclusion and exclusion criteria
- study design (presence of control group, randomized, qualitative/quantitative, retrospective/prospective)
- definition of concept maps used in the paper
- description of how concept maps are used in the *undergraduate* training of medical students
- teaching area where concept maps are used
- sample size
- resources (cost, time, resources needed to implement)
- description of the type of teacher training in concept maps use
- instruments used to assess the concept maps
- assessment of *critical thinking* acquired within the use of concept maps (educational impact)
- interventions and comparators
- quantitative studies: Intervention outcome(s), in accordance with Kirkpatrick’s level (Boet *et al.*, 2012) (Table 1)
- qualitative studies: identifying patterns in meaning across the data to derive themes
- conclusions
- lessons learned as stated by the authors
- risk of bias of study design for quantitative studies, using Medical Education Research Quality Instrument (MERSQI) score (Table 2)
- risk of bias for qualitative studies using Critical Appraisal Skills Programme (CASP) checklist (CASP 2018) (Table 3)
- risk of bias of reporting (Table 4)

Quality Assessment

Two major areas that will be considered: quality of the study design and quality of reporting to support replicability.

The MERSQI score for methodological evaluation of medical education studies (Cook & Reed 2015) will be used to assess the study design of nonqualitative research (Table 2).

The CASP checklist will be used as an appraisal tool for the qualitative studies. It will consider three sections: Are the results of the study valid? (Section A) What are the results? (Section B) Will the results help locally? (Section C) (Table 3).

A visual Red-Amber-Green (RAG) ranking system as previously used by Gordon (Gordon *et al.*, 2018) and Stojan (Stojan *et al.*, 2021), will be employed to assess risk of bias in reporting. The areas assessed will include underpinning theories, resources, setting, education (pedagogy), and content (Table 4). Items will be judged to be of high quality (Green), unclear quality (Yellow), or low quality (Red).

Synthesis of evidence

Narrative Summary (Description)

Descriptive analysis will be used to summarize the data from the studies published on assessing the use of concept mapping by medical students. A table will be developed to summarize key data, including geographic distribution of articles, study design, teaching area, Kirkpatrick's levels, and study purpose of research.

Mixed methods synthesis (Justification and clarification)

To answer the justification question "Whether these studies have impacted the student's critical thinking" we will perform quantitative synthesis. Homogenous outcome data, including any form of evaluation (Kirkpatrick's outcomes) will be considered for meta-analysis. To answer the clarification question, "How and why have these interventions had educational impact?" we will use thematic analysis. Direct quotations will be extracted from papers concerning the explicit use of theories, limitations, lessons learnt and conclusions.

Reporting the results

We will provide a descriptive numerical summary and a qualitative thematic analysis. Quantitative summaries of the characteristics, settings, context, year of publication, types of study design, and sample size of the included studies, will be presented using text and tables. Qualitative data will be labelled, coded, and categorized, and analysis previously described will be performed to summarise the results. An attempt to integrate both methodologies will be carried out, using mixed-methods (Pearson *et al.*, 2015). With the Bayesian method we could incorporate the qualitative and quantitative evidence in the same step of the analysis. Data from each report, whether qualitative or quantitative, will be treated the same way, with an integrated model, maximizing the findings (Crandell *et al.*, 2011).

We will report the results and produce the outcome that refers to the overall purpose or the review questions. For that purpose, we will use the STructured apprOach to the Reporting In healthcare education of Evidence Synthesis (STORIES) statement (Gordon & Gibbs 2014) and BEME guidance (Hammick *et al.*, 2010). We will discuss implications for future research and practice.

Pilot search

Some preliminary research was carried out, to refine the review questions aims and objectives. The search terms, strategy and dates used are presented below.

search date	databases	search terms	results
24.01.2022	ScienceDirect	("concept map" OR "concept mapping" OR "cognitive map" OR "cognitive mapping" OR "visual map" OR "visual mapping") AND "medical education" AND "critical thinking" – Limit "review articles and research articles"	54
27.01.2022	Pubmed	(("critical thinking") OR ("meaningful learning")) AND ("medical education") AND (("concept* map*") OR ("cognitive map*"))	34

	ERIC	cognitive map* OR "concept* map*" OR "visual map*") AND "medical education" AND "critical thinking" OR "meaningful learning"	91
28.01.2022	Web of Science	("knowledge map"* OR "concept* map*" OR "visual map*") AND "medical education" AND ("critical thinking" OR "meaningful learning")	50
	Scopus	ALL (("knowledge map"* OR "concept* map*" OR "visual map*") AND "medical education" AND ("critical thinking" OR "meaningful learning")) – Limit MEDICINE	14

In the search performed we selected some of these results, that met the selection criteria, as examples:

- Torre DM, Daley B, Stark-Schweitzer T, Siddartha S, Petkova J, Ziebert M. A qualitative evaluation of medical student learning with concept maps. Med Teach 2007;29(9–10):949–55. Available from: https://doi.org/10.1080/01421590701689506
- Brondfield, S., Seol, A., Hyland, K. et al. Integrating Concept Maps into a Medical Student Oncology Curriculum. J Canc Educ 36, 85–91 (2021). https://doi.org/10.1007/s13187-019-01601-7
- Maryam A, Mohammadreza D, Abdolhussein S, Ghobad R, Javad K. Effect of Concept Mapping Education on Critical Thinking Skills of Medical Students: A Quasi-experimental Study. Ethiop J Health Sci. 2021 Mar;31(2):409-418. doi: 10.4314/ejhs.v31i2.24. PMID: 34158793; PMCID: PMC8188091.
- Laight DW. Attitudes to concept maps as a teaching/learning activity in undergraduate health professional education: influence of preferred learning style. Med Teach. 2004 May;26(3):229-33. doi: 10.1080/0142159042000192064. PMID: 15203499.

Project Timetable

BEME protocol: April 2022
Literature search: May - June 2022
Screening Articles and Extracting Data: June 2022 - September 2022
Manuscript writing: September - November 2022

Conflict of Interest Statement

The authors have no financial, personal, political, institutional, or other conflicts of interest to report.

Plans for Updating the Review

5 years

Changes to the protocol

We will record any changes to the protocol as amendments and communicate the changes with a rationale to BEME.

Table 1 *- Kirkpatrick classification (Boet et al., 2012).*

Level	**Details**
1	Perception of training by subjects
2a	Change of attitudes of subjects
2b	Change of knowledge and/or skills of subjects
3	Changes of behaviour of subjects
4a	Change in professional practice
4b	Change in patients' condition

Table 2 *– Medical Education Research Quality Instrument (MERSQI).*

Domain	**MERSQUI Item**	**Score**
Study Design	Single group cross-sectional or single-group posttest only	1
	Single-group pretest and posttest	1.5
	Nonrandomized, 2 groups	2
	Randomized controlled trial	3
Sampling: institutions	1	0.5
	2	1
	3	1.5
Sampling: response rate	Not applicable	
	< 50% or not reported	0.5
	50%–74%	1
	≥ 75%	1.5
Type of data	Assessment by study participant	1
	Objective	3
Validity evidence for evaluation instrument scores	Not applicable	
	Content	1
	Internal structure	1
	Relationships to other variables	1
Data analysis	Descriptive analysis only	1
	Beyond descriptive analysis	2
	Data analysis appropriate for study design and type of data	1
Outcomes	Satisfaction, attitudes, perceptions, opinions, general facts	1
	Knowledge, skills	1.5
	Behaviors	2
	Patient/health care outcomes	3

Table 3 *– CASP Checklist: 10 questions for qualitative research (www.casp-uk.net).*

Section A – Are the results valid?		Yes	Can't Tell	No	Comments
1	Was there a clear statement of the aims of the research?				
2	Is a qualitative methodology appropriate?				
3	Was the research design appropriate to address the aims of the research?				
4	Was the recruitment strategy appropriate to the aims of the research?				
5	Was the data collected in a way that addressed the research issue?				
6	Has the relationship between researcher and participants been adequately considered?				
Section B – What are the results?		Yes	Can't Tell	No	Comments
7	Have ethical issues been taken into consideration?				
8	Was the data analysis sufficiently rigorous?				
9	Is there a clear statement of findings?				
Section C – Will the results help locally?		Comments			
10	How valuable is the research?				

Table 4 *– Quality assessment / risk of bias in reporting (visual RAG ranking system).*

Bias source	**High quality**	**Unclear quality**	**Low Quality**
Underpinning bias (U)	Clear and relevant description of theoretical models or conceptual frameworks that underpin the development	Some limited discussion of underpinning, with minimal interpretation in the context of the study	No mention of underpinning
Resource bias (R)	Clear description of the cost / time / resources needed for the development	Some limited description of resources	No mention of resources
Setting bias (S)	Clear details of the educational context and learner characteristics of the study	Some description, but not significant as to support dissemination	No details of learner characteristics or setting
Educational bias (E)	Clear description of relevant educational methods employed to support delivery	Some educational methods mentioned but limited detail as to how applied	No details of educational methods
Content bias (C)	Provision of detailed materials (or details of access)	Some elements of materials presented or summary information	No educational content presented

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